Interim Report (end of year 2) for ONR grant N 000 14-90-J-4129

Iron and DOC Studies in the World Ocean

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Long term GOALS:

1. Determine if it feasible to conduct unenclosed mesoscale (~50-100 km^2) iron fertilization patch experiments in major-nutrient rich areas of the ocean in order to determine how phytoplankton blooms affect the distributions of nutrients, trace elements, radionuclides, dissolved gases, dissolved and particulate organ c carbon etc.

2. Determine whether glacial/interglacial ocean iron availability has a direct effect on ocean productivity which in turn leads to an inverse relationship to atmospheric carbon dioxide concentrations.

3. Perfect the methodology necessary for the accurate measurement of DOC and DON in sea water using the new high temperature catalytic oxidation technique of Sugimura and Suzuki.

4. With the accomplishment of goal 1, determine the relative importance of atmospheric, continental margin, and in situ biogenic DOC/DON input processes.

Near Term OBJECTIVES:

1. Complete planning and begin preparations for the performance of a 75 km^2 iron enrichment experiment to be performed 300 miles south of the Galapagos during the fall of 1993.

2. Complete intercalibration exercises for the measurement of dissolved organic carbon (DOC) and nitrogen (DON). In cooperation with Tindale and Duce, develop methodology for the measurement of atmospheric vapor phase DOC and DON.

APPROACH:

1. Our approach is to measure dissolved and particulate iron distributions in various ocean waters in order to demonstrate that ocean water is basically infertile unless iron is supplied via continental weathering (nearshore) or atmospheric dust input (offshore) processes.

2. In waters that have excess major nutrients, perform enrichment experiments that show that the addition of nannomolar amounts of iron will result in phytoplankton growth, not only in bottles but in unenclosed surface water masses as well.

3. Continue participation in intercalibration exercises until DOC methodology is mastered.

TASKS COMPLETED:

1. Samples were collected and experiments were performed successfully during the 1992 Equatorial Pacific cruise. Dissolved and particulate phases from the experiments were analyzed for chlorophyll, nutrients, POC, PON, oxygen, DOC, DON and dimethyl sulphide (DMS, the latter in cooperation with Peter Liss).

RESULTS:

1. In equatorial Pacific experiments, we found evidence that ratios of oxygen gas evolved to POC produced are on the order of 1.7 O_2 to 1 C instead of traditional values of 1.3. We also found that DMS is produced after active phytoplankton growth has stopped, thus it is futile to look for relationships between chlorophyll and DMS.

2. We have obtained DOC concentrations similar to those measured by Dr. Suzuki on replicate samples collected during the north Atlantic bloom cruise. However we were unable to find a relationship between apparent oxygen utilization and DOC.

ACCOMPLISHMENTS:

1. Developed the hypothesis that global iron availability and its effect on ocean phytoplankton productivity may be directly related to glacial/interglacial changes in atmospheric CO_2 abundance.

2. With the perfection of ultraclean techniques, we were among the first to show that open Pacific iron concentrations were so low that it was not possible for phytoplankton to grow without the addition of supplemental iron from atmospheric input processes.

3. Although there are countless historical examples for the terrestrial environment, we were the first to demonstrate that the lack of a trace element (iron) limits plant growth in the marine environment.

4. Although the concept of iron deficiency was very controversial initially, confirmation of our results has been obtained in 5 independent studies. The concept is now accepted as the most plausible explanation for high nutrient, low chlorophyll regions of the ocean.

----------1991/1992 Publications----------

PI-91 Martin, J.H. Iron still comes from above. Nature 353:123. (scientific correspondence)

PI-91 Martin, J.H. Iron, Liebig's Law and the Greenhouse. Oceanography 4:52-55.

PI-91 Martin, J.H., S.E. Fitzwater and R.M. Gordon. We still say iron deficiency limits phytoplankton growth in the subarctic Pacific (J. Geophys. Res. Oceans, 96: 20,699-20,700; a reply to Karl Banse).

PI-91 Martin, J.H., R.M. Gordon and S.E. Fitzwater. The case for iron. In: S.W. Chisholm and F.M.M. Morel (eds.): What controls phytoplankton production in nutrient-rich areas of the open sea? ASLO Symposium, Lake San Marcos, California. Feb 22-24, 1991. Limnol. Oceanogr. 36: 1793-1802.

PI-92 Martin, J .H. and S. E. Fitzwater. Dissolved organic carbon in the Atlantic, Southern and Pacific Oceans. Nature 356:699-700.

PI-92 Martin, J.H. Iron as a limiting factor in oceanic productivity, pp. 123-137, in: P. G. Falkowski and A. D. Woodhead (eds.), Primary Productivity and Biogeochemical Cycles in the Sea. Plenum Press New York.

PI-92 Martin, J.H., S. E. Fitzwater, R. M. Gordon, C. N. Hunter and S.J. Tanner. Iron, primary production, and carbon-nitrogen flux studies during the JGOFS North Atlantic bloom experiment. Deep-Sea Res. (in press).

PI-92 Fitzwater, S. E. and J. H. Martin. Notes on the JGOFS North Atlantic bloom experiment DOC-HTCO Intercalibration. A background paper for the DOC/DON workshop, Seattle July 1991. Mar. Chem. (in press).

----------Invited talks, seminars etc.----------

IC-91 The case for iron. ASLO Symposium; Lake San Marcos CA, Feb. 23, 1991.

IC-91 Iron as a limiting factor. Symposium on primary production and biogeochemical cycles in the sea. Brookhaven, N.Y. June 3, 1991.

IC-91 Iron as a limiting factor in the ocean. VIth International Symposium on Iron Nutrition and Interactions in Plants. Logan, Utah July 18, 1991.

IC-92 Iron as a limiting nutrient. Biogeochemical Ocean Atmosphere Transport meeting January 27, 1992. Bermuda Biological Station for Research (NATO Advanced Research Workshop)

IC-92 Role of Iron in the Ocean Carbon Cycle, Past, Present, Future. Feb. 7, 1992. Physical Sciences Colloquium at IBM Almaden Research Center San Jose CA

IC-92 Ocean productivity and iron nutrition of phytoplankton. Feb 19, 1992

Carnegie-Stanford Plant Science Seminars; Carnegie Institution of Washington, Stanford University, Palo Alto CA.

IC -92 JGOFS:Biogeochemical Carbon Cycle Studies in the Global Ocean. April 6, 1992. Autonomous Bio-Optical Ocean Observing Systems Symposium. Monterey CA

IC-92 Big Iron Experiments. July 1, 1992, Monterey Bay Aquarium Research Institute, Monterey, CA

IC-92 Big Iron Experiments. July 2, 1992, U.S. Navy Post-Graduate School, Monterey, CA.

IC-92 H. Burr Steinbach Visiting Scholar Lectures at WHOI July 20-24, 1992

July 21, The History of the Iron Controversy.
July 22, The Ocean in a Bottle: Recent Iron Enrichment Experiments in the Equatorial Pacific.
July 23, Getting the Ocean out of the Bottle: Plans for a 75 m^2 Iron Enrichment Experiment.